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ABSTRACT

Because health behavior is often concerned with dynamic constructs, a longitudinal approach to measurement is needed. The Longitudinal Guttman Simplex (LGS) is a measurement model developed especially for dynamic constructs exhibiting cumulative, unitary development measured longitudinally. Data from the Television Smoking Prevention Project, a large media-enhanced school-based smoking prevention study, were analyzed using the longitudinal Guttman scales. Subjects were seventh graders at the time of the first measurement. Other measurements were taken 3 months later and 1 and 2 years after the second measurement. Two data sets were created because of changes in the questionnaire. Data from seventh graders comprised Data Set 1 which contained items on smoking behavior and intentions asked at all four measurement times. Eighth graders provided data for Data Set 2 which contained two waves of data plus items on alcohol, marijuana, and smokeless tobacco use. A number of sets of items thought to form longitudinal Guttman scales were analyzed. The results demonstrated the importance of peer pressure in convincing adolescents to smoke. Other results suggest that experimentation with cigarettes and hard liquor occur at about the same time. The LGS scales could be used as dependent variables in multivariate analyses, and as a means of identifying adolescents who may be at high risk for drug abuse. The measurement scales used in the study are appended. (NRB)

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The Longitudinal Guttman Simplex: Applications to Health Behavior Data

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The Longitudinal Guttman Simplex: Applications to Health Behavior Data

Overview

Today's presentation is about a new approach to measurement in longitudinal data known as the Longitudinal Guttman Simplex, or LGS. First, I will present the idea of a dynamic construct, and give examples of a few of the many dynamic constructs in the health behavior area. Second, I will show that classical test theory was not developed with the measurement of dynamic constructs in mind, so a new approach to measurement is needed. The LGS model represents such an approach. Third, the LGS model will be discussed in detail. The LGS is a measurement model developed especially for dynamic constructs exhibiting cumulative, unitary development measured longitudinally. I will explain what is meant by cumulative, unitary development and what it has to do with Guttman scales. Fourth, assessing scale consistency will be discussed briefly. Finally, I will present two empirical examples of longitudinal Guttman scales relevant to the health behavior area.

Dynamic Constructs and Their Measurement

Precise measurement in behavioral research is a challenging task in and of itself, but because health behavior research is largely longitudinal the measurement issues are often especially difficult ones. In longitudinal research measurement is given a particularly challenging task, that of measuring not a stationary, static construct, but the change itself of a construct that evolves over time, i.e., a dynamic construct. Such an aim presents an

interesting psychometric problem: How are longitudinal scales measuring dynamic constructs to be identified and evaluated?

This is an important issue, because dynamic constructs are quite common in health behavior research. For example, onset of substance use is not an all-or-nothing phenomenon; it is the dynamic evolution of a behavior over time. Leventhal and Cleary (1980) and Flay et al. (1983) have both conceptualized the acquisition of cigarette smoking as a dynamic process. Kandell's stepping-stone hypothesis (1975) suggests that the acquisition of drug use is a dynamic process, as does the work of Donovan and Jessor (1983). Many other factors related to substance use, such as the personality and psychosocial factors thought to be involved in substance use onset, are also considered dynamic processes. Dynamic processes are particularly commonplace in research involving young people.

Of course, a large literature on the measurement of change exists, with contributions by such diverse authors as Baltes and Nesselroade (1979), Cronbach and Furby (1970) and Joreskog (1979). However, this methodological debate has been centered around the issue of what we call simple linear change, that is, a simple change in the level or amount of something. Simple linear change is the way most dynamic constructs currently are represented by researchers. Part of the reason for this emphasis on simple linear change undoubtedly has to do with the ready applicability of classical test theory. Usually the researcher concentrates on obtaining the most valid and reliable measurement possible at each wave in a longitudinal study, using traditional psychometric

procedures and treating the construct of interest more or less like a static construct being measured repeatedly.

However, while this is appropriate in some situations, it may not be appropriate where dynamic constructs are involved. The fact that dynamic constructs undergo change over time makes them fundamentally different from static constructs. Classical test theory was developed with a static true score in mind; that is, classical test theory is based on the assumption that constructs themselves are unchanging, and that any observed change is due to error. Where dynamic constructs are concerned, obviously the assumption of an unchanging true score cannot be justified.

A New Scaling Model

What is needed is a measurement model designed especially for dynamic constructs measured longitudinally. Recently such a model has been developed by Collins and Cliff (1985). This new scaling model for longitudinal data is called the Longitudinal Guttman Simplex, or LGS. The LGS model extends the more familiar Guttman simplex model (Guttman, 1950) to longitudinal data.

To understand the LGS model, it helps to think about how the development of a construct is reflected in a set of items measuring that construct. Suppose the construct is one of development in an increasing direction (rather than representing a decrease or decline of some kind). Then it would be expected that the proportion of people passing or endorsing each item would increase over time. However, an overall increase in proportion of people passing or endorsing each item in a set can occur even if the items are not

measuring the same construct. Clearly this one criterion is not enough to tell whether a set of items is measuring one and only one dynamic construct.

Before establishing criteria for telling whether all members of a set of items measure the same dynamic construct, the researcher must first have some idea of the type of development the construct of interest is undergoing. Certainly development can occur in various ways, each of which may be uniquely reflected by data. The LGS scaling model is designed for one specific sort of development, that is, cumulative, unitary development. By cumulative, we mean that as later stages or levels are reached, earlier ones are retained. By unitary, we mean that all subjects pass through the stages or levels in the same order. Table 1 shows a hypothetical example of a set of drug use items forming a LGS. This hypothetical example is modeled after Kandell's (1975) stepping-stone hypothesis. The process is cumulative because a subject who has tried marijuana has also tried alcohol, and a subject who has tried hard drugs has also tried alcohol and marijuana. The process is unitary because all subjects first try alcohol, then marijuana, then hard drugs.

Guttman Scales and Cumulative, Unitary Development

Thus, a longitudinal Guttman scale is a set of items representing cumulative, unitary development. To understand what cumulative, unitary development has to do with a Guttman scale of any type, it is necessary first to define a cross-sectional Guttman scale. The cross-sectional Guttman scale is what a researcher typically thinks of as a Guttman scale. It is a joint order between

items and persons such that the items are ordered by difficulty and the persons are ordered by ability. Table 2 shows a data set where items A, B, C, and D form a perfect Guttman scale. Item E clearly is not a member of the same scale.

Some years ago Hunt (1961) and others pointed out that in cross-sectional data this pattern is obtained when items representing cumulative, unitary development are administered to a cross-sectional sample of people representing a variety of ages. In this case the people would be ordered by age and the items would be ordered by their place in the developmental progression. However, this is less than satisfactory for two reasons. First, it makes the unrealistic assumption that development and age are perfectly correlated. Second, the inference that the items form a cumulative, unitary progression is a weak one, because the progress of individuals through the sequence has not been traced. In order to do such tracing, longitudinal data are needed. The LGS model defines a Guttman scale in longitudinal data.

A Hypothetical Example

Table 3 shows hypothetical data forming a longitudinal Guttman simplex. The hypothetical data involve two subjects, three items, and three times. The dynamic construct represented in these data is cumulative, i.e., when a subject responds "yes" to an item, he or she also responds "yes" to any earlier or less extreme items. It is also unitary, i.e., all subjects try the drugs in the same order. Note that for each subject there is a Guttman scale similar to the one shown in Table 1, except instead of a persons-items

order, these Guttman scales are items-times joint orders. Note also that the joint order is consistent across the two subjects. This is the essential feature of a LGS: a joint items-times order consistent across persons.

Table 3 illustrates two other interesting features of the LGS model. First, because human development is stochastic, people often develop at different rates. The LGS model makes no requirement that persons develop at the same rate, or that an individual subject develop at a consistent rate across time. Table 3 shows that at Time 1 and Time 2 Jerry is clearly the more experienced drug user, while at Time 3 Tom is more experienced. This is because between Time 2 and Time 3, Tom's drug use experience advanced more quickly than it did between Time 1 and Time 2. Despite this inconsistency in developmental rate, the development exhibited is still cumulative and unitary, and the data form a perfect LGS. Thus, the LGS model incorporates the stochastic nature of human development, making it a realistic model for many situations. Second, the LGS model can make use of more than two waves of data simultaneously, as illustrated in Table 3 where three waves were used. There is theoretically no limit on the number of waves of measurement included in a LGS. Relatively few statistical procedures have this feature, a state of affairs recently lamented by Rogosa and Willet (1985).

A formal axiomatic definition of the LGS model has been developed. A presentation of these axioms is outside the scope of the present talk, but details can be found in Collins and Cliff

(1985).

Assessing Consistency in Longitudinal Guttman Scales

A consistency index for longitudinal Guttman scales has been developed based upon the formal axiomatic definition mentioned above. This index, known as Index 13, reflects the degree to which observed data adhere to the LGS axioms. The index ranges between -1/3 and 1, with zero the expected value in random data. Index 13 has been shown in a Monte Carlo study (Collins, Dent, & Cliff, 1985) to be quite robust to variations in number of items, number of subjects, and number of times, while remaining sensitive to violations of LGS model axioms. Further details can be found in Collins et al. (1985).

Empirical Examples in the Health Behavior Area

Method. The two empirical examples in the present talk were drawn on data from the Television Smoking Prevention Project, a large media-enhanced school based smoking prevention study (Flay, Hansen, Johnson, & Sobel, 1983) that took place in Los Angeles. The students were in seventh grade at the time of the first measurement (December 1981/January 1982). Later measurements took place at April/May 1982, April/May 1983, and April/May 1984.

Two data sets were created for use in this presentation. Two data sets were needed because the questionnaire changed somewhat between the second and third waves of data collection, with alcohol, marijuana, and smokeless tobacco items added. Therefore, Data Set 1 contained a number of smoking behavior and intentions items that were asked on all four waves of data collection, while Data Set 2

contained only two waves of data, but included the additional items. In Data Set 1 the students were seventh graders at the outset, while in Data Set 2 the students were eighth graders at the outset. Because of the high turnover rate in the Los Angeles area schools, Data Set 2 is not simply a subset of Data Set 1, but contains many students who were measured for the first time at the third wave of data collection. In both data sets, only subjects with no missing data on any of the items were selected. As is common when questionnaire data are analyzed with a Guttman scaling procedure, items with more than two response categories were dichotomized.

Results. A number of sets of items that were thought to form longitudinal Guttman scales were analyzed using a computer program for calculating Index 13 and Index 13-if-item-deleted. Two of the more consistent scales are presented in Tables 4 and 5, with the items listed in order from earliest "yes" response to latest "yes" response. For example, in the Smoking Onset Scale, a subject would first answer "yes" to Item 1, then answer "yes" to Item 2 and to Item 1, etc. In the Drug Use Onset Scale, there are two pairs of items: 3a and b, and 8a and b. This indicates that neither of the two items seemed to precede the other, but rather the two items were endorsed at about the same point in the process.

The Smoking Onset Scale in Table 4 is interesting because it shows the role of peer pressure at various stages in the smoking onset process. It seems that having at least one good friend who has tried smoking is important for setting the whole process in motion. Then the adolescent goes on to experiment with smoking.

Later peer pressure becomes more intense. Note that the more direct peer pressure seems to come into play after the adolescent has already begun experimenting. First it takes prompting from a best friend, and a dare at that, to get the respondent to smoke; later the somewhat gentler pressure of an offer from a group of smoking friends works. In any case, this pressure seems to be a gateway to low-level regular smoking.

The Drug Use Onset scale in Table 5 suggests that experimentation with cigarettes and hard liquor occurs at about the same time. It may seem surprising that beer use comes so late in the sequence, but this item may tap somewhat heavier beer use. Questions 5, 6, and 7 may signal the beginning of problem use for these eighth/ninth graders, with heavier drinking and experimentation with marijuana. Finally, low-level regular smoking and use of smokeless tobacco seem, in this sample of Los Angeles youth, to occur at about the same point in the process. In fact, in this sample nearly half of those who reported having tried smokeless tobacco were low-level regular smokers.

Practical Uses of Longitudinal Guttman Scales

Scaling models can be used to serve two purposes. One purpose is to confirm the existence of *a priori* constructs in data. The scales in Tables 4 and 5 resulted from the LGS model applied in this way. Another purpose of scaling is to develop good measures of particular constructs. For example, a researcher might be interested in developing a longitudinal measure of cigarette use onset. The procedure is much like that used to develop any other

measure. The researcher would administer a set of items to an appropriate group of subjects over time, and then examine the consistency of the item set in terms of Index 13. By examining Index 13-if-item-deleted the researcher can get an idea of which items, if any, should be taken out of the scale. In this way poor items can be weeded out. The result is a uniquely sensitive measure of cumulative, unitary development.

Once longitudinal Guttman scales have been developed, they are useful in further analyses. For example, because the use of the LGS model enhances measurement of dynamic constructs exhibiting cumulative, unitary development, statistical power can be improved under some circumstances by using longitudinal Guttman scales as dependent variables. Another area where longitudinal Guttman scales can be useful is flagging problems before they become too severe. For example, items making up a longitudinal Guttman scale of drug use onset could be given periodically to a group of adolescents. If adolescents reached a certain point in the process, they might be considered at particularly high risk, and targeted for special prevention efforts.

Summary

The LGS, a new scaling model developed especially for dynamic constructs measured longitudinally, extends the more familiar Guttman simplex model to longitudinal data. The essential feature of the LGS model is a joint items-times order consistent across persons. The LGS is a model of development where all persons pass through a series of stages or levels in the same stage order,

and as later stages or levels are passed, the ability to pass earlier stages or levels is retained. That is, the LGS is a model of cumulative, unitary development. A consistency index for longitudinal Guttman scales has been developed, and is currently known as Index 13. The purpose of Index 13 is to help the researcher develop longitudinal Guttman scales in empirical data. Practical uses of longitudinal Guttman scales include using the scales as dependent variables in multivariate analyses, and using them to flag adolescents who may be at high risk for drug abuse.

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Table 1

Hypothetical Items Making up a Longitudinal Guttman Scale

Item	Response
I have tried alcohol.	Yes or No
I have tried marijuana.	Yes or No
I have tried hard drugs.	Yes or No

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Table 2

Data Forming a Cross-Sectional Guttman Scale

(a Persons-Items Joint Order)

With One Item That Does Not Belong

		ITEMS				
		A	B	C	D	E
	1	0	0	0	0	1
	2	1	0	0	0	0
SUBJECTS	3	1	1	0	0	1
	4	1	1	1	0	0
	5	1	1	1	1	1

Table 3

Data Forming a LGS

	Tom			Jerry		
	Alcohol	Mari-juana	Hard Drugs	Alcohol	Mari-juana	Hard Drugs
Time 1	no	no	no	yes	no	no
Time 2	yes	no	no	yes	yes	no
Time 3	yes	yes	yes	yes	yes	no

Table 4

Cigarette Use Onset Scale

Index 13 = .66

Item Dichotomized to:

(1) Have any of your good friends tried smoking?

(2) Have you ever smoked even a puff of a cigarette?

(3) Have you ever smoked more than one whole cigarette?

(4) If your best friend dared you to smoke a cigarette, would you do it?

(5) If some of your good friends were sitting around smoking and they offered you a cigarette, would you smoke it?

(6) Do you currently smoke regularly, at least on a monthly basis?

Table 3

Drug Use Onset Scale

Index 13 = .71

Item Dichotomized to:

(1) Have you ever tried drinking wine?

(2) Have you ever smoked even a puff of a cigarette?

(3a) Have you ever had any other (not beer or wine) alcoholic beverages?

(3b) Have you ever smoked more than one whole cigarette?

(4) Have you had more than one entire beer in your life?

(5) Have you ever been drunk?

(6) Have you ever smoked marijuana?

(7) Do you drink more than once a month?

(8a) Do you currently smoke regularly, at least on a monthly basis?

(8b) Have you ever chewed, dipped, or snuffed tobacco?